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(54) **MANAGING MULTI-LEVEL SERVICE LEVEL AGREEMENTS IN CLOUD-BASED NETWORKS**

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H04L 12/24	(2006.01)
G06F 9/455	(2006.01)
G06F 9/50	(2006.01)
G06Q 10/06	(2012.01)
H04L 12/911	(2013.01)

(52) **U.S. Cl.**

CPC ***H04L 41/5019*** (2013.01); ***G06F 9/45533*** (2013.01); ***G06F 9/5072*** (2013.01); ***G06F 9/5077*** (2013.01); ***G06Q 10/0639*** (2013.01); ***H04L 47/70*** (2013.01)

(58) **Field of Classification Search**

CPC G06Q 10/10
USPC 718/101
See application file for complete search history.

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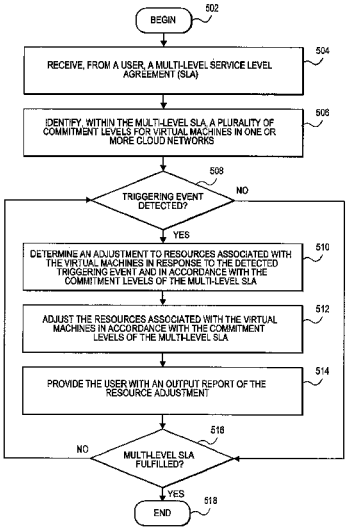
(57) **ABSTRACT**

Embodiments relate to managing multi-level service level agreements (SLAs) in cloud-based networks. A resource managing module can manage resources in the cloud-based networks in response to the detection of one or more triggering events. In embodiments, the triggering events can be changeovers in time periods, or meeting or exceeding thresholds associated with end user operation of the resources in the cloud-based networks. The multi-level SLAs can specify how to adjust the resources in the cloud-based networks in response to the detection of the triggering events. The resource managing module can adjust applicable resources in the cloud-based networks as specified by the multi-level SLAs.

20 Claims, 5 Drawing Sheets



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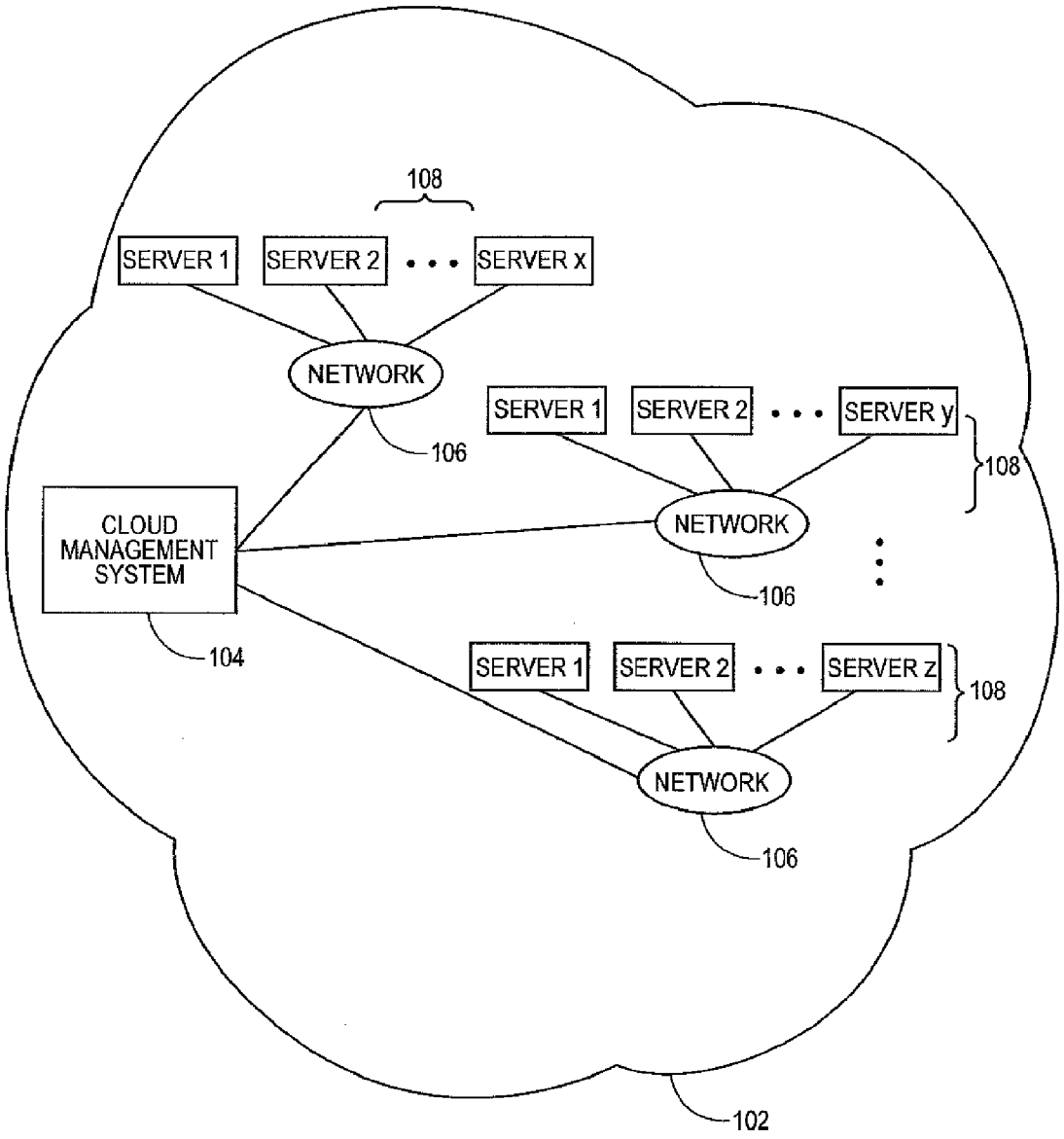
108
SERVER 1
SERVER 2
SERVER x
NETWORK
106
SERVER 1
SERVER 2
SERVER y
108
CLOUD MANAGEMENT SYSTEM
NETWORK
106
104
SERVER 1
SERVER 2
SERVER z
108
NETWORK
106
102

FIG. 1

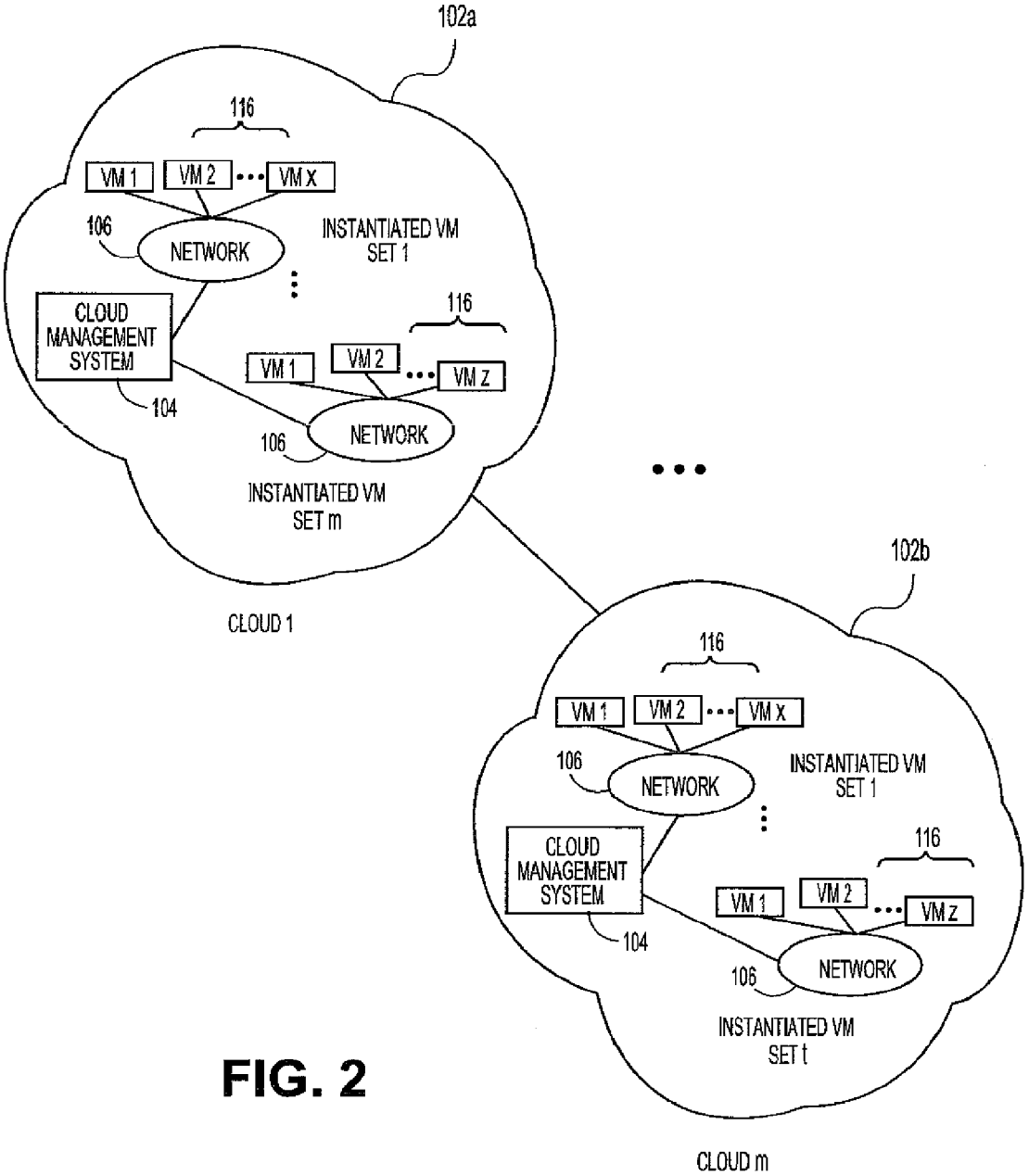
102a
116
VM 1
VM 2
VM X
106
NETWORK
INSTANTIATED VM SET 1
CLOUD MANAGEMENT SYSTEM
104
116
VM 1
VM 2
VM Z
106
NETWORK
INSTANTIATED VM SET m
CLOUD 1
102b
116
VM 1
VM 2
VM X
106
NETWORK
INSTANTIATED VM SET 1
CLOUD MANAGEMENT SYSTEM
104
116
VM 1
VM 2
VM Z
106
NETWORK
INSTANTIATED VM SET t
CLOUD m

FIG. 2

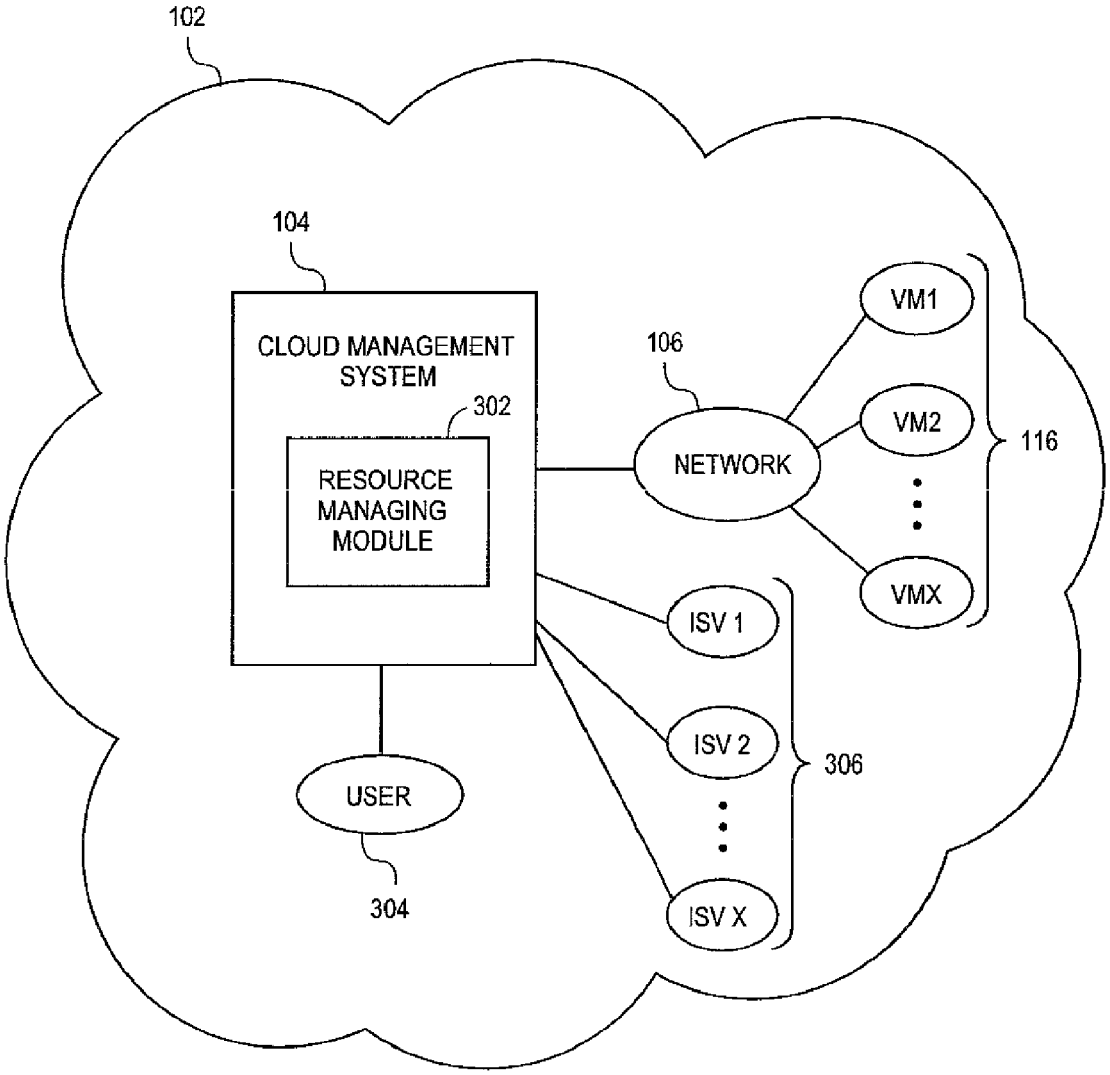
102
104
CLOUD MANAGEMENT SYSTEM
302
RESOURCE MANAGING MODULE
106
NETWORK
VM1
VM2
VMX
116
ISV 1
ISV 2
ISV X
306
USER
304

FIG. 3

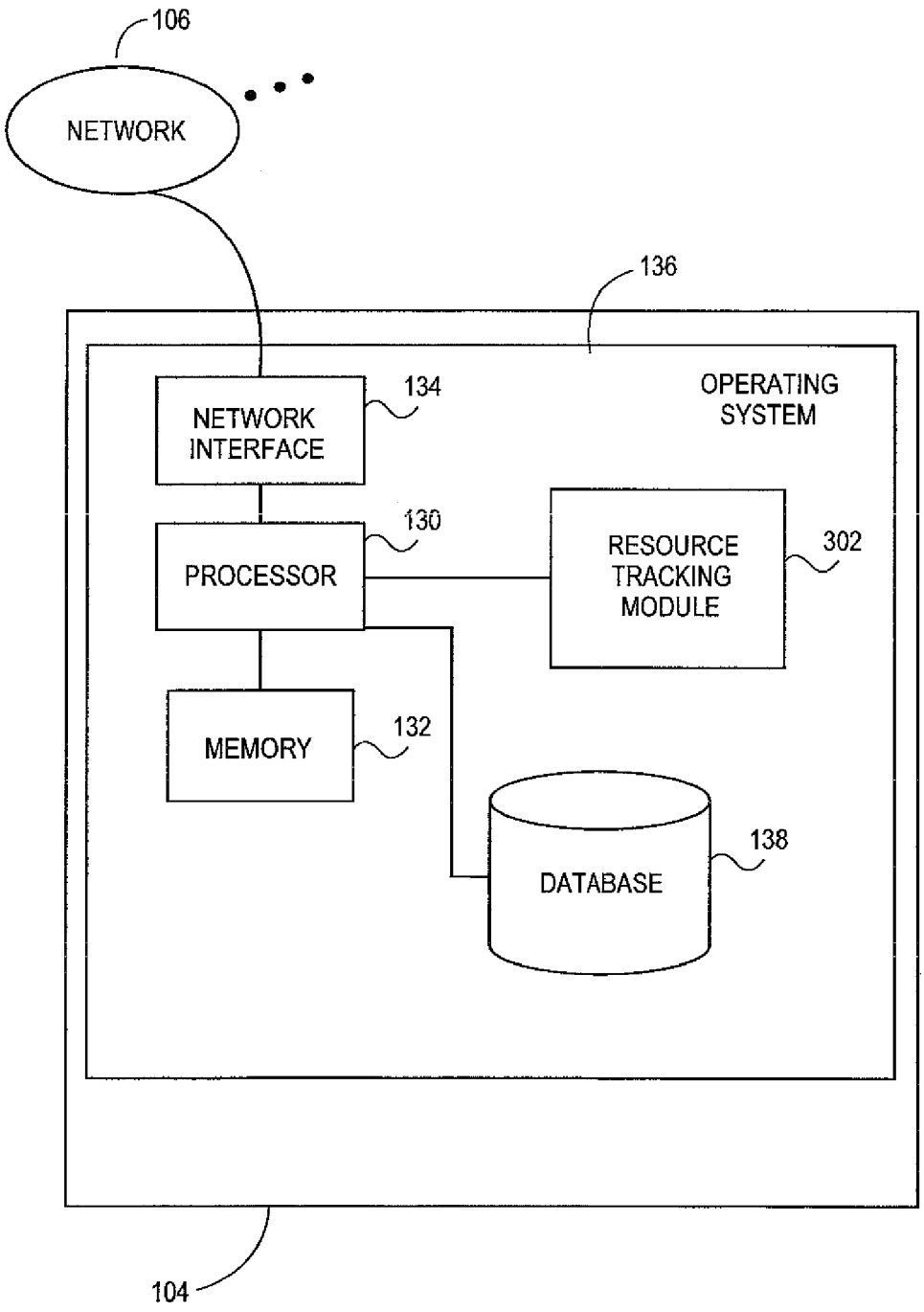
106
NETWORK
136
NETWORK INTERFACE
134
OPERATING SYSTEM
PROCESSOR
130
RESOURCE TRACKING MODULE
302
MEMORY
132
DATABASE
138
104

FIG. 4

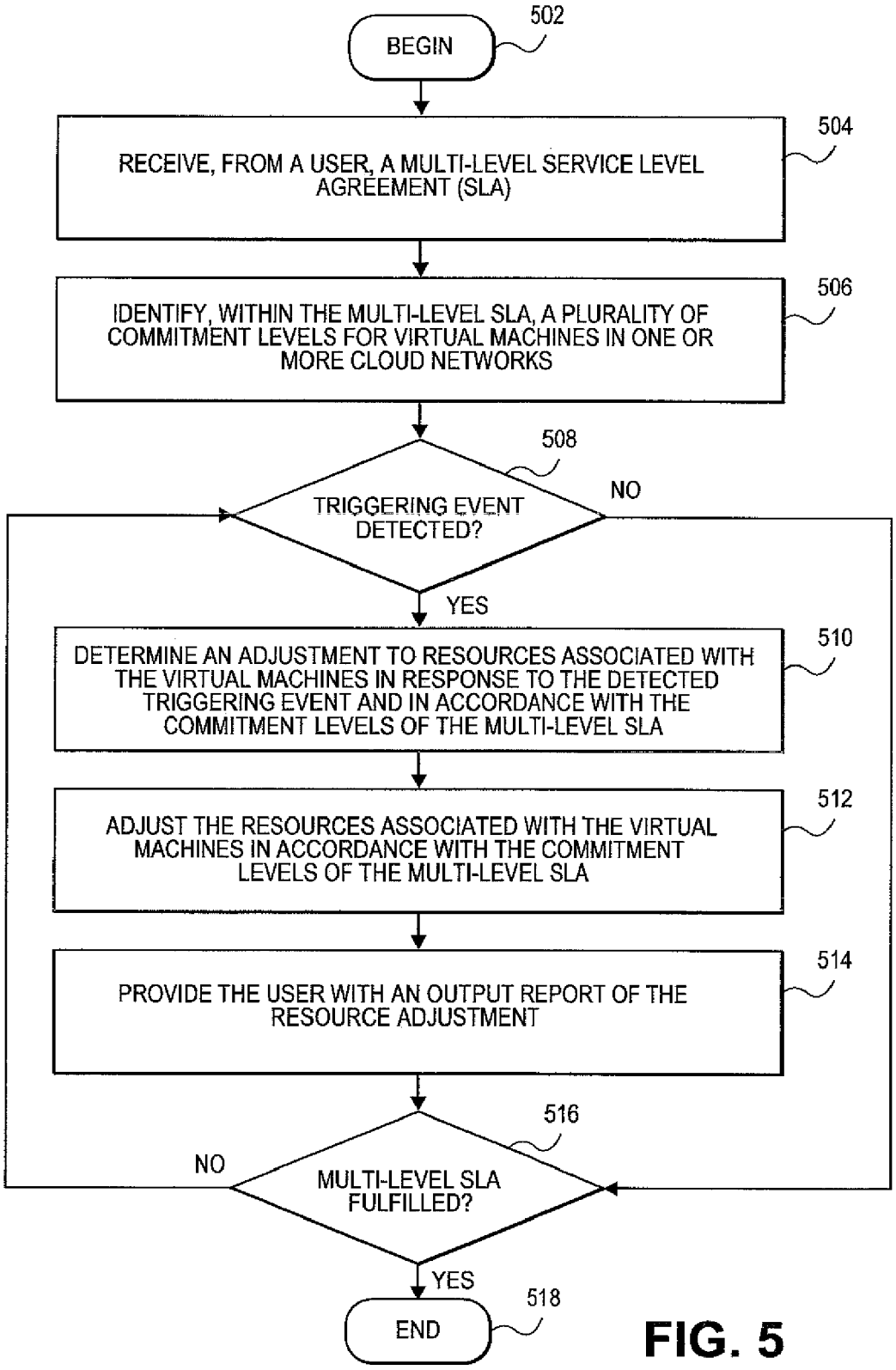
BEGIN
502
RECEIVE, FROM A USER, A MULTI-LEVEL SERVICE LEVEL AGREEMENT (SLA)
504
IDENTIFY, WITHIN THE MULTI-LEVEL SLA, A PLURALITY OF COMMITMENT LEVELS FOR VIRTUAL MACHINES IN ONE OR MORE CLOUD NETWORKS
506
TRIGGERING EVENT DETECTED?
508
NO
YES
DETERMINE AN ADJUSTMENT TO RESOURCES ASSOCIATED WITH THE VIRTUAL MACHINES IN RESPONSE TO THE DETECTED TRIGGERING EVENT AND IN ACCORDANCE WITH THE COMMITMENT LEVELS OF THE MULTI-LEVEL SLA
510
ADJUST THE RESOURCES ASSOCIATED WITH THE VIRTUAL MACHINES IN ACCORDANCE WITH THE COMMITMENT LEVELS OF THE MULTI-LEVEL SLA
512
PROVIDE THE USER WITH AN OUTPUT REPORT OF THE RESOURCE ADJUSTMENT
514
MULTI-LEVEL SLA FULFILLED?
516
NO
YES
END
518

FIG. 5

MANAGING MULTI-LEVEL SERVICE LEVEL AGREEMENTS IN CLOUD-BASED NETWORKS

REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 12/789,660, filed May 28, 2010, which issued as U.S. Pat. No. 8,909,783, which is incorporated herein by reference, in its entirety, for all purposes.

FIELD

The present teachings relate to systems and methods for managing multi-level service level agreements (SLAs) in cloud-based networks, and more particularly to platforms and techniques for managing and adjusting resources in the cloud-based networks in response to the detection of one or more triggering events.

BACKGROUND OF RELATED ART

A service level agreement (SLA) is an agreement between a user and a cloud network provider. The user, for example, a company, is associated with a plurality of end users of a cloud-based network provided by the cloud network provider. The SLA specifies that the cloud network provider agrees to commit an amount of resources associated with virtual machines in the cloud network for use by the end users during operation of software products and applications. In return, the user can be charged a specified rate in proportion to the amount of committed resources. For example, in the SLA, the cloud network provider can commit to provide or maintain a specific amount of server uptime, persistent storage, software application instantiation, network performance, cloud storage, support response time, and other elements. Further, the SLA can detail any remedies or adjustments for any service failure associated with the use of the resources in the cloud network. Vendors to the user, such as independent software vendors (ISVs), can allow their software products and applications to be executed and operated by the end users via the virtual machines in the cloud network.

The SLA, however, does not account for peak or low usage times, an increase in the number of end users operating the virtual machines, and other situations that can cause the usage of the resources in the cloud network to fluctuate. For example, there can be times or situations in which the user can be forced to pay for on-demand service if the resource usage exceeds what is specified in the agreement. Further, there can be times or situations for which a segment of the resources in the cloud network can remain unused by end users.

Therefore, it may be desirable to provide systems and methods for managing multi-level SLAs in cloud-based networks. In particular, it may be desirable to agree upon a resource commitment that can vary based on various factors or triggering events.

DESCRIPTION OF DRAWINGS

FIG. **1** illustrates an overall cloud system architecture in which various embodiments of the present teachings can be practiced;

FIG. **2** illustrates an overall cloud system architecture including multiple cloud arrangements in which various embodiments of the present teachings can be practiced in another regard, according to various embodiments;

FIG. **3** illustrates an exemplary network configuration that can be used in systems and methods for managing multi-level service level agreements in cloud-based networks, according to various embodiments;

FIG. **4** illustrates an exemplary hardware configuration for a cloud management system, according to various embodiments; and

FIG. **5** illustrates a flowchart for managing multi-level service level agreements in cloud-based networks, according to various embodiments.

DESCRIPTION OF EMBODIMENTS

Embodiments of the present teachings relate to systems and methods for managing multi-level SLAs in cloud-based networks. In particular, embodiments relate to platforms and techniques for managing and adjusting resources in the cloud-based networks available for end user operation in response to detecting one or more triggering events. In embodiments, the end user operation can be a set of users accessing, via a set of instantiated virtual machines, application or product resources provided by one or more vendors, such as ISVs.

Embodiments described herein can be implemented in or supported by a cloud network architecture that can support multi-level SLAs. As used herein, a "user" can refer a person, customer, subscriber, administrator, corporation, organization, or other entity contracting into a multi-level SLA with a cloud network provider. In embodiments, the user can be a vendor itself, such as an ISV. Further, as used herein, a "cloud" can comprise a collection of resources that can be invoked to instantiate a virtual machine, process, or other resource for a limited or defined duration. Further, as used herein, a multi-level SLA can be an agreement between a user and a cloud network provider. For example, the user can be a company or other entity with an online storefront that can utilize software applications of a vendor that are supported by resources of the cloud network provider. In particular, the multi-level SLA can specify various levels of resources, such as virtual machines, to be provided to the user by the cloud network provider. The end users associated with the user can utilize the provided resources to operate products and applications of the vendor. In embodiments, the cloud network provider can charge the user various rates based on the levels of resources allocated for end user operation, among other factors. For example, the cloud network provider can charge the end user more for a high level of resources. As used herein, the resources can be hardware such as, for example, servers, device drivers, storage such as hard drives, databases, random access memory (RAM) and other memory, processors, multimedia cards, and the like; software, bundled with, installed on, or otherwise associated with the hardware; and/or other resources. In embodiments, vendors such as ISVs can supply software resources for use with other resources. Resources can also include communications resources, such as ports or channels provided to a virtual machine or other machine or process in the cloud. Resources can likewise include services, such as Web-based services deployed in the cloud, for example security or identity management services and/or other resources.

In embodiments, a resource managing module can be independent of any user or vendor to the user, and independent of any one cloud network. In embodiments, the resource managing module can be implemented on a cloud

management system and can be configured to monitor resource usage and manage resource availability in one or more cloud networks. For example, the resource managing module can be configured to monitor end user operation of the applications and products via one or more instantiated virtual machines. Further, the resource managing module can be configured to detect one or more triggering events, and adjust resources associated with a set of virtual machines in one or more cloud networks in response to the one or more triggering events and based on specifications of a multi-level SLA. In embodiments, the one or more triggering events can be a changeover of specified time periods, or can be a usage condition threshold, such as conditions relating to an increase or decrease in end user use of the resources, being reached or exceeded. It should be appreciated that other triggering events are envisioned.

Instead of situations where a user may be forced to pay, on an on-demand basis, for resources that exceed the resources specified in a conventional SLA, or situations where the user may be charged an amount for resources that is disproportionate to the amount actually used by the end users, the multi-level SLA can allow for both predicted or unexpected changes in end user operation within the cloud networks while also being cost-efficient. Further, the multi-level SLA can decrease the chance of cloud providers not being able to support the necessary end user operation. Therefore, users can save money throughout the life of the multi-level SLA. Further, the management of the multi-level SLAs can make for a more streamlined process.

As shown for example in FIG. **1**, the collection of resources supporting a cloud **102** can comprise a set of resource servers **108** configured to deliver computing components needed to instantiate a virtual machine, process, or other resource. For example, one group of resource servers can host and serve an operating system or components thereof to deliver to and instantiate a virtual machine. Another group of resource servers can accept requests to host computing cycles or processor time, to supply a defined level of processing power for a virtual machine. A further group of resource servers can host and serve applications to load on an instantiation of a virtual machine, such as an email client, a browser application, a messaging application, or other applications or software. Other types of resource servers are possible.

In embodiments, the entire set of resource servers **108** or other hardware or software resources used to support the cloud **102** along with its instantiated virtual machines is managed by a cloud management system **104**. The cloud management system **104** can comprise a dedicated or centralized server and/or other software, hardware, and network tools that communicate via network **106** such as the Internet or other public or private network with all sets of resource servers to manage the cloud **102** and its operation. To instantiate a new set of virtual machines, a user can transmit an instantiation request to the cloud management system **104** for the particular type of virtual machine that the user desires to invoke for its intended application. A user can for instance make a request to instantiate a set of virtual machines configured for email, messaging or other applications from the cloud **102**. The request can be received and processed by the cloud management system **104**, which identifies the type of virtual machine, process, or other resource being requested. The cloud management system **104** can then identify the collection of resources necessary to instantiate that machine or resource. In embodiments, the set of instantiated virtual machines or other resources can for example comprise virtual transaction servers used to support Web storefronts, or other transaction sites.

In embodiments, the user's instantiation request can specify a variety of parameters defining the operation of the set of virtual machines to be invoked. The instantiation request, for example, can specify a defined period of time for which the instantiated machine or process is needed. The period of time can be, for example, an hour, a day, or other increment of time. In embodiments, the user's instantiation request can specify the instantiation of a set of virtual machines or processes on a task basis, rather than for a predetermined amount of time. For instance, a user could request resources until a software update is completed. The user's instantiation request can specify other parameters that define the configuration and operation of the set of virtual machines or other instantiated resources. For example, the request can specify an amount of processing power or input/output (I/O) throughput the user desires to be available to each instance of the virtual machine or other resource. In embodiments, the requesting user can for instance specify a service level agreement (SLA) acceptable for their purposes. Other parameters and settings can be used. One skilled in the art will realize that the user's request can likewise include combinations of the foregoing exemplary parameters, and others.

When the request to instantiate a set of virtual machines or other resources has been received and the necessary resources to build that machine or resource have been identified, the cloud management system **104** can communicate with one or more of the set of resource servers **108** to locate resources to supply the required components. The cloud management system **104** can select providers from the diverse set of resource servers **108** to assemble the various components needed to build the requested set of virtual machines or other resources. It may be noted that in some embodiments, permanent storage such as hard disk arrays may not be included or located within the set of resource servers **108** available to the cloud management system **104**, since the set of instantiated virtual machines or other resources may be intended to operate on a purely transient or temporary basis. In embodiments, other hardware, software or other resources not strictly located or hosted in the cloud can be leveraged as needed. For example, other software services that are provided outside of the cloud **102** and hosted by third parties can be invoked by in-cloud virtual machines. For further example, other non-cloud hardware and/or storage services can be utilized as an extension to the cloud **102**, either on an on-demand or subscribed or decided basis.

With the resource requirements identified, the cloud management system **104** can extract and build the set of virtual machines or other resources on a dynamic or on-demand basis. For example, one set of resource servers **108** may respond to an instantiation request for a given quantity of processor cycles with an offer to deliver that computational power immediately and guaranteed for the next hour. A further set of resource servers **108** can offer to immediately supply communication bandwidth, for example on a guaranteed minimum or best-efforts basis. In other embodiments, the set of virtual machines or other resources can be built on a batch basis or at a particular future time. For example, a set of resource servers **108** may respond to a request for instantiation at a programmed time with an offer to deliver the specified quantity of processor cycles within a specific amount of time, such as the next 12 hours.

The cloud management system **104** can select groups of servers in the set of resource servers **108** that match or best

match the instantiation request for each component needed to build the virtual machine or other resource. The cloud management system **104** can then coordinate the integration of the completed group of servers from the set of resource servers **108**, to build and launch the requested set of virtual machines or other resources. The cloud management system **104** can track the combined group of servers selected from the set of resource servers **108**, or other distributed resources that are dynamically or temporarily combined, to produce and manage the requested virtual machine population or other resources.

In embodiments, the cloud management system **104** can generate a resource aggregation table that identifies the various sets of resource servers that will be used to supply the components of the virtual machine or process. The sets of resource servers can be identified by unique identifiers such as, for instance, Internet protocol (IP) addresses or other addresses. The cloud management system **104** can register the finalized group of servers in the set of resource servers **108** contributing to an instantiated machine or process.

The cloud management system **104** can then set up and launch the initiation process for the virtual machines, processes, or other resources to be delivered from the cloud. The cloud management system **104** can for instance transmit an instantiation command or instruction to the registered group of servers in the set of resource servers **108**. The cloud management system **104** can receive a confirmation message back from each participating server in the set of resource servers **108** indicating a status regarding the provisioning of their respective resources. Various sets of resource servers may confirm, for example, the availability of a dedicated amount of processor cycles, amounts of electronic memory, communications bandwidth, or applications or other software prepared to be served.

As shown for example in FIG. **2**, the cloud management system **104** can then instantiate one or more than one set of virtual machines **116**, or other processes based on the resources supplied by the registered set of resource servers **108** (shown in FIG. **1**). In embodiments, the cloud management system **104** can instantiate a given number, for example, 10, 500, 1000, or other numbers of virtual machines to be made available to users on a network **106**, such as the Internet or other public or private network. Each virtual machine can be assigned an instantiated machine ID that can be stored in the resource aggregation table, or other record or image of the instantiated population. Additionally, the cloud management system **104** can store the duration of each virtual machine and the collection of resources utilized by the complete set of instantiated virtual machines **116**.

In embodiments, the cloud management system **104** can further store, track, and manage a user's identity and associated set of rights or entitlements to software, hardware, and other resources. Each user that populates a set of virtual machines in the cloud can have specific rights and resources assigned and made available to them. The cloud management system **104** can track and configure specific actions that a user can perform, such as provision a set of virtual machines with software applications or other resources, configure a set of virtual machines to desired specifications, submit jobs to the set of virtual machines or other host, manage other users of the set of instantiated virtual machines **116** or other resources, and other privileges or actions. The cloud management system **104** can further generate records of the usage of instantiated virtual machines to permit tracking, billing, and auditing of the services consumed by the user. In embodiments, the cloud management system **104** can for example meter the usage and/or duration of the set of instantiated virtual machines **116**, to generate subscription billing records for a user that has launched those machines. Other billing or value arrangements are possible.

The cloud management system **104** can configure each virtual machine to be made available to users of the network **106** via a browser interface, or other interface or mechanism. Each instantiated virtual machine can communicate with the cloud management system **104** and the underlying registered set of resource servers **108** via a standard Web application programming interface (API), or via other calls or interfaces. The set of instantiated virtual machines **116** can likewise communicate with each other, as well as other sites, servers, locations, and resources available via the Internet or other public or private networks, whether within a given cloud **102***a*, **102***b* or between clouds.

It may be noted that while a browser interface or other front-end can be used to view and operate the set of instantiated virtual machines **116** from a client or terminal, the processing, memory, communications, storage, and other hardware as well as software resources required to be combined to build the virtual machines or other resources are all hosted remotely in the cloud **102***a*, **102***b*. In embodiments, the set of virtual machines **116** or other resources may not depend on or require the user's own on-premise hardware or other resources. In embodiments, a user can therefore request and instantiate a set of virtual machines or other resources on a purely off-premise basis, for instance to build and launch a virtual storefront or other application.

Because the cloud management system **104** in one regard specifies, builds, operates and manages the set of instantiated virtual machines **116** on a logical level, the user can request and receive different sets of virtual machines and other resources on a real-time or near real-time basis, without a need to specify or install any particular hardware. The user's set of instantiated machines **116**, processes, or other resources can be scaled up or down immediately or within a short period of time on an on-demand basis, if desired. In embodiments, the various sets of resource servers that are accessed by the cloud management system **104** to support a set of instantiated virtual machines **116** or processes can change or be substituted, over time. The type and operating characteristics of the set of instantiated virtual machines **116** can nevertheless remain constant or almost constant, since instances are assembled from abstracted resources that can be selected and maintained from diverse sources based on uniform specifications.

In terms of network management of the set of virtual machines **116** that have been successfully configured and instantiated, the cloud management system **104** can perform various network management tasks including security, maintenance, and metering for billing or subscription purposes. The cloud management system **104** of a given cloud **102***a*, **102***b* can, for example, install or terminate applications or appliances on individual machines. The cloud management system **104** can monitor operating virtual machines to detect any virus or other rogue process on individual machines, and for instance terminate the infected application or virtual machine. The cloud management system **104** can likewise manage an entire set of instantiated virtual machines **116** or other resources on a collective basis, for instance, to push or deliver a software upgrade to all active virtual machines. Other management processes are possible.

In embodiments, more than one set of virtual machines can be instantiated in a given cloud at the same, overlapping, or successive times. The cloud management system **104** can,

in such implementations, build, launch, and manage multiple sets of virtual machines based on the same or different underlying set of resource servers **108**, with populations of different instantiated virtual machines **116** such as may be requested by different users. The cloud management system **104** can institute and enforce security protocols in a cloud **102***a*, **102***b* hosting multiple sets of virtual machines. Each of the individual sets of virtual machines can be hosted in a respective partition or sub-cloud of the resources of the main cloud **102***a*, **102***b*. The cloud management system **104** of a cloud can for example deploy services specific to isolated or defined sub-clouds, or isolate individual workloads/processes within the cloud to a specific sub-cloud. The subdivision of the cloud **102***a*, **102***b* into distinct transient sub-clouds or other sub-components which have assured security and isolation features can assist in establishing a multiple user or multi-tenant cloud arrangement. In a multiple user scenario, each of the multiple users can use the cloud platform as a common utility while retaining the assurance that their information is secure from other users of the overall cloud system. In further embodiments, sub-clouds can nevertheless be configured to share resources, if desired.

In embodiments, and as also shown in FIG. **2**, the set of instantiated virtual machines **116** generated in a first cloud **102***a* can also interact with a set of instantiated virtual machines or processes generated in a second, third or further cloud **102***b*. Further, the cloud management system **104** of the first cloud **102***a* can interface with the cloud management system **104** of the second cloud **102***b*, to coordinate those domains and operate the clouds and/or virtual machines or processes on a combined basis. The cloud management system **104** of a given cloud **102***a*, **102***b* can track and manage individual virtual machines or other resources instantiated in that cloud, as well as the set of instantiated virtual machines or other resources in other clouds.

In the foregoing and other embodiments, the user making an instantiation request or otherwise accessing or utilizing the cloud network can be a person, customer, subscriber, administrator, corporation, organization, or other entity. In embodiments, the user can be or include another virtual machine, application or process. In further embodiments, multiple users or entities can share the use of a set of virtual machines or other resources.

FIG. **3** illustrates an exemplary network configuration that can be used in systems and methods for managing a multi-level SLA in cloud-based networks. In embodiments as shown, the cloud management system **104** can comprise a resource managing module **302** configured to interface with the set of instantiated virtual machines **116** via the network **106** to detect one or more triggering events, and adjust resources associated with the set of instantiated virtual machines **116** based on the one or more triggering events and in accordance with a multi-level SLA between a cloud network provider and a user **304**. It should be appreciated that the resource managing module **302** can be implemented on other hardware and/or software components configured to interface with the other components and entities described herein. Further, it should be appreciated that the resource managing module **302** can be configured to interface with additional clouds (not shown in figures) and associated resources, such as virtual machines, of the additional clouds.

In embodiments, the user **304** can be an owner, administrator, company, or other entity who can provide, provision, or otherwise deliver software applications, or other software, hardware, or other products or services, such as products and services of one or more ISVs **306**, to end users accessing the cloud **102**. In embodiments, the end users can access the set of instantiated virtual machines **116** located in the cloud **102**. It should be appreciated that the user **304** can have one or more multi-level SLAs with one or more cloud providers to provide software product(s) and/or maintain end users in one or multiple clouds, and/or across multiple products and/or product lines. The resource managing module **302** can adjust resources associated with the set of instantiated virtual machines **116** in accordance with specifications of any applicable multi-level SLAs. In embodiments, the multi-level SLAs can specify resource availability related to the use of one or more of the set of instantiated virtual machines **116** by end users to operate software applications, products, services, and the like provided by, for example, the one or more ISVs **306**. The resource managing module **302** can be configured to communicate with the user, **304**, the one or more ISVs **306**, the set of instantiated virtual machines **116**, and/or other machines, hosts, nodes, or resources. In embodiments, the resource managing module **302** can track and manage the set of instantiated virtual machines or other resources instantiated in the cloud **102**, as well as the set of instantiated virtual machines or other resources instantiated in other clouds

In embodiments, the multi-level SLA can be a multi-tiered SasS subscription plan for users, such as an entity utilizing products of an ISV, according to embodiments of the present teachings. For example, the user **304** can enter into a multi-level SLA with a cloud network provider whereby the cloud network provider can commit, in a first commitment level, to provide 1,000 virtual machines for use by end users to operate software products associated with an ISV during peak weekday business hours (e.g. Monday-Friday, 9:00 AM-5:00 PM), provide, in a second commitment level, 500 virtual machines for use by end users during off-peak weekday hours (e.g. Monday-Friday, 5:00 PM-9:00 AM), and provide, in a third commitment level, 200 virtual machines for use by end users during weekend hours (e.g. all day Saturday and Sunday), wherein the cloud network provider can bill the user monthly for a period of 12 months. This exemplary multi-level SLA can have one or more triggering events, such as the changeover points from peak weekday business hours to off-peak weekday hours to weekend hours. Accordingly, in this example, the amount of available virtual machines can be reduced in response to detecting when the time is 5:00 PM on a weekday. It should be appreciated that other multi-level SLAs with varying terms and specifications are envisioned.

The resource managing module **302** can be configured to examine a multi-level SLA between a cloud provider and the user **304** to determine a plurality of commitment levels for the set of instantiated virtual machines **116** based on detected triggering events. For example, the resource managing module **302** can detect the changeover to an off-peak time period, such as when the time changes to 5:00 PM, and correspondingly reduce the resources associated with the set of instantiated virtual machines **116** from a first commitment level to a second commitment level, as specified by the multi-level SLA. Similarly, the resource managing module **302** can detect the changeover to a peak time period, such as when the time changes to 9:00 AM, and correspondingly increase the resources associated with the set of instantiated virtual machines **116** from the second commitment level to a third commitment level, as specified by the multi-level SLA. In embodiments, the triggering events can be the reaching or exceeding of usage condition thresholds related to the end user operation of the set of instantiated virtual machines **116**. For example, the resource managing module

302 can increase resources associated with the set of instantiated virtual machines 116 from a first commitment level to a second commitment level if end user operation reaches or exceeds a threshold level. Similarly, the resource managing module 302 can decrease resources associated the set of instantiated virtual machines 116 from the second commitment level to a third commitment level if end user operation reaches or falls below a low-threshold level.

In embodiments, the resource managing module 302 can terminate or instantiate one or more virtual machines in the same cloud 102 or in multiple clouds 102. Further, the resource managing module 302 can terminate a set of instantiated virtual machines 116 in one cloud 102 and instantiate another set of virtual machines 116 in another cloud 102 to effectively "roll over" resources available to end users from one cloud-based network to another. In embodiments, the resource managing module 302 can be configured to provide an output report detailing any resource adjustment to the user 304 or other entity. For example, the output report can be provided to the user 304 at fixed or varied intervals, or at any point during the terms of the multi-level SLA.

FIG. 4 illustrates an exemplary diagram of hardware and other resources that can be incorporated in a cloud management system 104 configured to communicate with a set of instantiated virtual machines 116 (as shown in FIG. 2) via one or more networks 106, according to embodiments. In embodiments as shown, the cloud management system 104 can comprise a processor 130 communicating with memory 132, such as electronic random access memory, operating under control of or in conjunction with operating system 136. Operating system 136 can be, for example, a distribution of the Linux™ operating system, the Unix™ operating system, or other open-source or proprietary operating system or platform. Processor 130 also communicates with one or more computer readable storage medium 138, such as hard drives, optical storage, databases, and the like. Processor 130 further communicates with network interface 134, such as an Ethernet or wireless data connection, which in turn communicates with one or more networks 106, such as the Internet or other public or private networks.

Processor 130 can also communicate with computer readable storage medium 138 and the resource managing module 302, to execute control logic, allow for managing multi-level SLAs as described herein, and control the operation of virtual machines and other resources in cloud 102. Other configurations of cloud management system 104, associated network connections, and other hardware and software resources are possible.

FIG. 5 illustrates a flowchart for overall multi-level SLA management processing in a cloud computing environment, according to various embodiments. In 502, processing can begin. In 504, a multi-level SLA can be received from a user. In embodiments, the multi-level SLA can be an agreement between a cloud provider and the user for the cloud provider to provide a set of virtual machines in one or more cloud networks for use by end users to operate software applications associated with the vendor via the set of virtual machines. In 506, a plurality of commitment levels for virtual machines in the one or more cloud networks can be identified. In embodiments, each of the plurality of commitment levels can describe a resource commitment for a specific event trigger, such as a time period changeover or a usage condition threshold being reached or exceeded. In 508, a triggering event can be detected. In embodiments, the triggering event can be detected when a specified time period ends or when a threshold use condition is reached or exceeded, and can trigger a change from one of the commitment levels to another of the commitment levels.

In 510, an adjustment to resources associated with the virtual machines can be determined in response to the detected triggering event and in accordance with the commitment levels of the multi-level SLA. In embodiments, the cloud management system 104 can examine the commitment levels of the multi-level SLA and determine an increase or decrease in associated virtual machine resources based on the detected triggering event. In 512, the resources associated with the virtual machines can be adjusted in accordance with the commitment levels of the multi-level SLA. In embodiments, the cloud management system 104 can terminate or instantiate one or more virtual machines in the same cloud network or in multiple cloud networks. Further, the cloud management system 104 can terminate one or more virtual machines in one cloud network and instantiate one or more virtual machines in another cloud network to effectively "roll over" resources available to end users from one cloud network to another. In 514, an output report of the resource adjustment can be provided to the user. In embodiments, the output report can be provided upon each resource adjustment, at varied or fixed intervals, or at other points during the term of the multi-level SLA. In 516, the terms of the multi-level SLA can be checked for fulfillment. If the multi-level SLA has not been fulfilled, processing can return to 508 for detection of a triggering event. If the multi-level SLA has been fulfilled, processing can proceed to end at 518.

The foregoing description is illustrative, and variations in configuration and implementation may occur to persons skilled in the art. For example, while embodiments have been described which operate using one resource managing module 302 and associated cloud management system 104, in embodiments, one or more of resource managing module 302 and associated cloud management system 104, and/or other servers, data stores, and/or other logic or resources can be used. For further example, while embodiments have been described in which cloud resources and subscription plans are modified or adjusted, in embodiments, the subscription plans, associated fees, and resources associated with the plans can be modified or adjusted according to any combination and at any time or interval. Other resources described as singular or integrated can in embodiments be plural or distributed, and resources described as multiple or distributed can in embodiments be combined. The scope of the present teachings is accordingly intended to be limited only by the following claims.

What is claimed is:

1. A method, comprising:

identifying, by a processor, within a multi-level service level agreement (SLA) for a cloud network, a first commitment level indicating a first amount of resources needed by a first amount of instantiated virtual machines and a second commitment level indicating a second amount of resources needed by a second amount of instantiated virtual machines, the cloud network provided by a plurality of providers and including at least two providers;

detecting a triggering event that indicates a change should be made from the first commitment level to the second commitment level;

generating a resource aggregation table comprising a plurality of sets of resources in the cloud network, each set of resources from a provider, the resources in the set of resources in conformance with the second amount of resources identified by the second commitment level;

selecting at least one set of resources from the plurality of sets from a first provider to meet the second commitment level; and

adjusting, by the processor, resources used within the cloud network from the first commitment level to the second commitment level using the selected set of resources in response to detecting the triggering event.

2. The method of claim **1**, wherein the first amount of instantiated virtual machines and the second amount of instantiated virtual machines are constant.

3. The method of claim **1**, further comprising:

responsive to the second amount of resources being greater than the first amount of resources, selecting the at least one set of resources from the plurality of sets from a second provider to meet the second commitment level.

4. The method of claim **1**, wherein the first provider is a private network.

5. The method of claim **1**, wherein the selected set of resources comprises at least one of a server, a device driver, a storage device, a database, a random access memory (RAM), a memory device, a processor, a multimedia card, or associated software.

6. The method of claim **1**, wherein adjusting the resources associated with the virtual machines in the cloud network comprises adjusting an amount of instantiated virtual machines within the cloud network.

7. The method of claim **1**, wherein adjusting the resources associated with the virtual machines in the cloud network comprises:

terminating a first set of virtual machines within the cloud network; and

instantiating a second set of virtual machines within a second cloud network.

8. The method of claim **1**, wherein the triggering event corresponds to a time period schedule.

9. The method of claim **1**, wherein the triggering event corresponds to an end user operation condition of the virtual machines in the cloud network.

10. The method of claim **1**, wherein the first amount of resources supports a first application from a first independent software vendor (ISV).

11. The method of claim **1**, further comprising providing an output report to a user.

12. The method of claim **11**, further comprising determining whether terms of the multi-level SLA have been fulfilled or not fulfilled, wherein the output report to the user indicates whether the terms of the SLA have been fulfilled or not fulfilled.

13. The method of claim **1**, further comprising:

identifying, within the multi-level SLA, a third commitment level indicating a third amount of instantiated virtual machines for the virtual machines in the cloud network;

detecting a second triggering event that indicates a change should be made from the second commitment level to the third commitment level; and

adjusting resources associated with the virtual machines in the cloud network from the second commitment level to the third commitment level in response to detecting the second triggering event.

14. A system comprising:

an interface to a cloud network and in which virtual machines are hosted; and

a processor operatively coupled to the interface, the processor to:

identify, within a multi-level service level agreement (SLA) for the cloud network, a first commitment level indicating a first amount of resources needed by a first amount of instantiated virtual machines and a second commitment level indicating a second amount of resources needed by a second amount of instantiated virtual machines, the cloud network provided by a plurality of providers and including at least two providers;

detect a triggering event that indicates a change should be made from the first commitment level to the second commitment level;

generate a resource aggregation table comprising a plurality of sets of resources in the cloud network, each set of resources from a provider, the resources in the set of resources in conformance with the second amount of resources identified by the second commitment level;

select at least one set of resources from the plurality of sets from a first provider to meet the second commitment level; and

adjust resources used within the cloud network from the first commitment level to the second commitment level using the selected set of resources in response to detecting the triggering event.

15. The system of claim **14**, wherein operating characteristics of the first amount of instantiated virtual machines and the second amount of instantiated virtual machines remain constant.

16. The system of claim **14**, further comprising:

responsive to the second amount of resources being greater than the first amount of resources, select the at least one set of resources from the plurality of sets from a second provider to meet the second commitment level.

17. The system of claim **14**, wherein the first provider is a private network.

18. The system of claim **14**, wherein the selected set of resources comprises at least one of a server, a device driver, a storage device, a database, a random access memory (RAM), a memory device, a processor, a multimedia card, or associated software.

19. The system of claim **14**, wherein adjust the resources associated with the virtual machines in the cloud network comprises adjust an amount of instantiated virtual machines within the cloud network.

20. A non-transitory computer readable storage medium comprising data that, when executed by a processor, causes the processor to:

identify, by the processor, within a multi-level service level agreement (SLA) for a cloud network, a first commitment level indicating a first amount of resources needed by a first amount of instantiated virtual machines and a second commitment level indicating a second amount of resources needed by a second amount of instantiated virtual machines, the cloud network provided by a plurality of providers and including at least two providers;

detect a triggering event that indicates a change should be made from the first commitment level to the second commitment level;

generate a resource aggregation table comprising a plurality of sets of resources in the cloud network, each set of resources from a provider, the resources in the set of resources in conformance with the second amount of resources identified by the second commitment level;

select at least one set of resources from the plurality of sets from a first provider to meet the second commitment level; and

adjust, by the processor, resources used within the cloud network from the first commitment level to the second commitment level using the selected set of resources in response to detecting the triggering event.

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